Improved direct torque control strategy performances of electric vehicles induction motor

Hassane Bachiri, Brahim Gasbaoui, Abdelkader Ghezouani, Nouria Nair
SGRE Laboratory, Electrical Engineering Department, Ecole Tahri Mohamed Bechar University, Béchar, Algeria

Article Info

Article history:

Received Jun 30, 2021
Revised Mar 25, 2022
Accepted Apr 10, 2022

Keywords:

3WES
Artificial neural network ANN
Direct torque control DTC
Induction motor IM
Speed control PI

ABSTRACT

A three-wheeled electric scooter (3WES) with two control techniques is modeled and simulated in this study. The conventional direct torque control (C-DTC) and the DTC based on a neural network artificial multi layers (ANN-DTC). The objective is to assess the traction system's response to the control approach. by 3WES taking into account the dynamics of the scooter, the range and the energy consumption of the battery. The 3WES was simulated numerically using the MATLAB/Simulink environment, which is powered 1.5 kW by two induction motors integrated into the rear wheels. Where the reference speeds of the rear wheels detected using a differential electronic. This can possibly cause it to synchronize the wheel speed in any curve. Each wheel's speed was controlled by two types of regulators, PI and ANN, to increase stability and reaction time (in terms of set point tracking, disturbance rejection and rise time). The proposed ANN-DTC control technique reduces torque, stator flux, and current ripple by roughly 35%. While the range of 3WES has increased by approximately 8.062 m, the battery power consumption has decreased by nearly 0.25%.

Corresponding Author:

Hassane Bachiri
SGRE Laboratory Engineering, Electrical Engineering Department, Tahri Mohamed Bechar University
JQ38+JWG, Béchar, Algeria
Email: bachirihassane@yahoo.com

1. INTRODUCTION

Air pollution is a major problem in modern society. All contributes to health concerns, while CO2 emissions have an adverse effect on the ecosystem [1]. The transport industry is a significant source of greenhouse gases. The European Union (EU) has developed a plan to increase use of electric vehicles on the continent. in order to minimize pollution produced by passenger transport. In the EU, the emissions associated with the additional power generation necessary for electric transmission are less than those associated with fossil-fueled types of transportation are currently in use. Compared to ICE vehicles, electric vehicles are currently unreasonably expensive., according to studies. Electrification using two-wheel electric technology is a possibility, particularly in metropolitan areas [2]. Within the last year, electric scooters have gained popularity as a more environmentally friendly alternative to regular scooters.

For the most part, industrial applications use the squirrel cage induction machine as their primary electric actuator. the latter is distinguished by its resilience, dependability, low cost, and low maintenance needs. However, as a result of its modeling, a nonlinear, closely coupled system is created. and multivariate equations, its dynamic behavior is frequently rather complicated. Additionally, many state variables, such as flows, are not quantifiable. These restrictions necessitate the development of increasingly sophisticated control algorithms for real-time torque and flow control in these devices. Numerous control techniques for achieving this goal have been presented in the literature. Traditional controls were put to the test in the mid-

1980s by a new asynchronous machine control approach known as direct torque control (DTC) [3], [4]. Its operation is based on direct determination of the control pulses supplied to the voltage inverter switches in order to keep the electromagnetic torque and stator flux within two predetermined hysteresis bands. This use of the technique enables the decoupling of torque control and flux to be achieved without the need of pulse width modulation (PWM) or coordinate transformation.

Additionally, the main benefits of DTC are the rapid dynamic torque response, the minimum of dependence on rotor parameters, and the absence of coordinate transformations [5], [6]. However, this technique has two significant disadvantages: on the one hand, the switching frequency is highly variable; on the other side, the amplitude of the torque and stator flux ripples is poorly controlled across the whole working speed range. It should be observed that torque ripples add to the noise and vibration generated by the rotating shaft, resulting in fatigue. To further mitigate the impact of these phenomena on the service life of electric actuators, intelligent strategies are regarded to be beneficial.

Currently, artificial intelligence techniques are known for their power to solve problems related to the automation of industrial processes, such as the control, command, identification and estimation of parameters of electrical systems. The intelligent technique based on fuzzy logic belongs to the class of knowledge model-based systems. It is applied more and more in the control of the induction machine and the adaptation of its command [7]-[9]. Fuzzy logic-based approaches are considered to be a very powerful solution for controlling nonlinear systems or systems for which there are no mathematical models. Neural networks are distinguished by their capacity for processing, learning and approximation which is another technique of artificial intelligence. They are considered to be a completely different class from classical computers [10]-[12].

In this study, we propose to propose a DTC control using intelligent strategies. We are interested in the DTC control of an induction machine that propels an electric scooter's two-wheel drive via artificial neural networks. This effort will conclude with a comparison of the results obtained using ANN-DTC and conventional DTC control.

2. MODEL OF THE ELECTRIC MOTORIZATION BY IN-WHEEL IM

An artificial neural network-direct torque control (ANN-DTC) is used to execute direct control of the coupling based on knowledge of stator flux amplitude and location, and as a result, a balance must be struck between modeling complexity and precision when developing control techniques. based in another on the knowledge of the amplitude and the position of the stator flux, one presents the complete model of the machine in the reference of park linked to the stator reference frame (α-β) is put in the form of following state as shown Figure 1.

$$\dot{x} = Ax + Bu \tag{1}$$

$$\text{Such as: } x = \left[i_{s\alpha} i_{s\beta} \varphi_{s\alpha} \varphi_{s\beta}\right]^T,\ u = \left[u_{s\alpha} u_{s\beta}\right]^T \tag{2}$$

$$A = \begin{bmatrix} -\eta & \omega_r & K & \frac{\omega_r}{\sigma L_s} \\ \omega_r & -\eta & -\frac{\omega_r}{\sigma L_s} & K \\ R_s & 0 & 0 & 0 \\ 0 & R_s & 0 & 0 \end{bmatrix};\ B = \begin{bmatrix} \frac{1}{\sigma L_s} & 0 \\ 0 & \frac{1}{\sigma L_s} \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \tag{3}$$

With : $\sigma = 1 - \frac{M^2}{L_s L_r}$, $T_s = \frac{L_s}{R_s}$, $T_r = \frac{L_r}{R_r}$, $\omega_r = p\Omega_r$, $K = \frac{1}{\sigma L_s T_r}$, $\eta = -\frac{1}{\sigma}\left(\frac{1}{T_r} + \frac{1}{T_s}\right)$

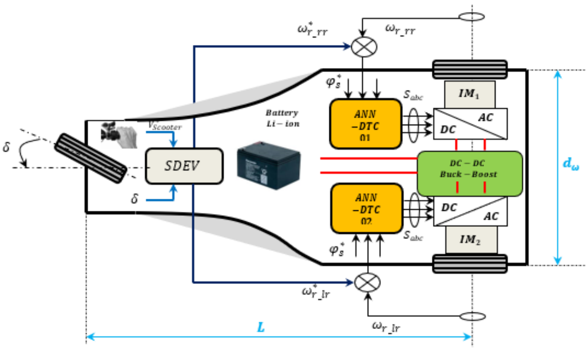


Figure 1. The configuration of 3WDES three-wheel drive electric scooter

3. WHEEL INDUCTION MOTOR DRIVE BASED ON CONVENTIONAL DTC

A technique for controlling induction motor torque directly was developed in the mid-1980s by I. Takahashi and T. Noguchi [13], [14], as well as Debembrok. DTC stands for direct-to-consumer (direct torque control). The DTC works by measuring the control pulses sent to the voltage inverter's switches directly. This is done to keep the stator flux and electromagnetic torque within predetermined hysteresis zones. This method's implementation allows the flow and torque control to be separated. At its output, the voltage inverter reaches seven phase plane positions, which correspond to eight voltage vector sequences: [15]-[19]. Figure 2 illustrates a three-wheeled electric scooter's induction motor's DTC block diagram incorporated within the wheels. The flux may be estimated using measurements of the induction machine's stator current and voltage magnitudes [20].

$$\varphi_{s\alpha} = \int_0^t (v_{s\alpha} - R_s i_{s\alpha})\, d \tag{4}$$

$$\varphi_{s\beta} = \int_0^t \left(v_{s\beta} - R_s i_{s\beta}\right) dt \tag{5}$$

The stator flux modulus is written:

$$\varphi_s = \sqrt{{\varphi_{s\alpha}}^2 + {\varphi_{s\beta}}^2} \tag{6}$$

The area N_i It determines the location of the vector φ_s based on the components $\varphi_{s\alpha}$ and $\varphi_{s\beta}$. The angle $\theta_s$between the frame of reference $(\alpha - \beta)$and the vectorφ_s, is equal to [21].

$$\theta_s = arctg\left(\frac{\varphi_{s\beta}}{\varphi_{s\alpha}}\right) \tag{7}$$

Once the two components of the flux have been determined, the electromagnetic torque may be calculated using the [22]:

$$T_{em} = \frac{3}{2} p\left[\varphi_{s\alpha} i_{s\beta} - \varphi_{s\beta} i_{s\alpha}\right] \tag{8}$$

Table 1 illustrates the DTC control truth table [18].

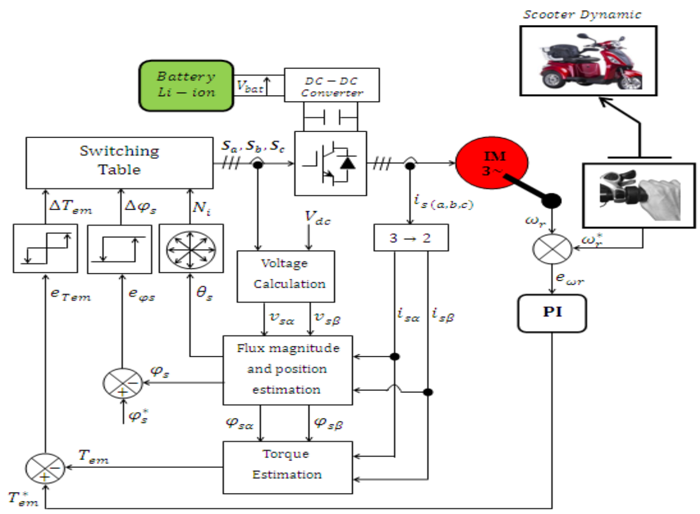


Figure 2. 3WES conventional direct torque control for in-wheel induction motor drive

Table 1. Switching table for conventional direct torque control (CDTC)

Sector N_i		S_1	S_2	S_3	S_4	S_5	S_6
$\Delta\varphi_s = 1$	$\Delta T_{em} = 1$	V_2	V_3	V_4	V_5	V_6	V_1
	$\Delta T_{em} = 0$	V_7	V_0	V_7	V_0	V_7	V_0
	$\Delta T_{em} = -1$	V_6	V_1	V_2	V_3	V_4	V_5
$\Delta\varphi_s = 0$	$\Delta T_{em} = 1$	V_3	V_4	V_5	V_6	V_2	V_1
	$\Delta T_{em} = 0$	V_0	V_7	V_0	V_7	V_0	V
	$\Delta T_{em} = -1$	V_5	V_6	V_1	V_2	V_3	V_4

4. WHEEL INDUCTION MOTOR DRIVE BASED ON NEURONE ARTIFICIEL ANN

To enhance the speed reference tracking performance of the ANN-DTC control method, the PI controller has been replaced by ANN artificial neuron network type controller as shown in Figure 3. The neural network that we used is a multilayer network with local connection which uses the back-propagation algorithm [22] for their learning [23]-[26]. The figure illustrates the neural network, we used to be a multilayer network with local connection which uses the back-propagation algorithm for their learning [27]. The structure of the neural network used is shown in the Figure 4.

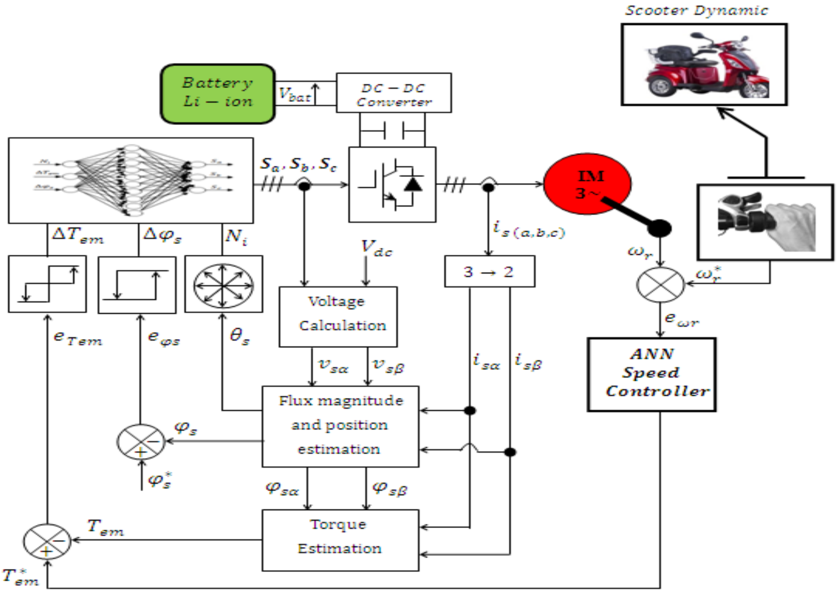


Figure 3. ANN-DTC for the three-wheel electric scooter 3WDES in-wheel induction motor drive

4.1. Design of ANN-DTC controller

The PI controller has been combined by an ANN artificial neuron network type controller to increase the performance of the ANN-DTC control strategy in terms of speed reference tracking. The neural network that we utilized is a multilayer network with local connections that learns using the back-propagation technique [28]. The structure of the neural network used is shown in the Figure 4. To generate the ANN controller by Matlab/Simulink where we have chosen 64 hidden layers and 03 output layers with activation functions of type 'Tansig' and 'Purelin' respectively [29]. This network weights and biases are updated using a back-propagation technique called the Levenberg-Marquardt (LM) algorithm.

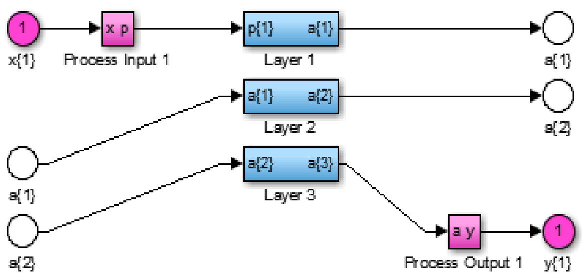


Figure 4. Internal structure of the ANN speed controller

5. SPEED CYCLE PROPOSED FOR THE 4WD ELECTRIC VEHICLE

We recommended a ten-second speed cycle. The cycle speed profile is seen in Figure 5. This trajectory is comprised of seven distinct stages. The first phase involves rolling along a straight road at a speed of 30 km / h; the second phase involves imposing a right turn on the scooter via a set point of the steering angle (δ=25 °); as it is illustrated in Figure 6 the third phase involves rolling along a straight road at the same speed; and the fourth phase

involves imposing a left turn on the scooter via a steering angle (δ=-15 °). The sixth step involves the scooter rolling along a straight road at a speed of 30 kilometers per hour. In the sixth phase, the 3WES accelerates to 50Km / h while it climbs a road inclined at a 10 ° inclination (slope). Finally, (07) depicts the deceleration phase, with the scooter traveling at a speed of 5Km / h. The road' limitations are listed in Table 2.

Table 2. Specified driving route topology

Phase	Time (Sec)	Event information	scoter speed Km/h
01	0s < t <1.5s	Straight road	30 km/h
02	1.5s < t <2.5s	Curved road side right	30 km/h
03	2.5s < t <4s	Straight road	30 km/h
04	4s < t <5s	Curved road side left	30 km/h
05	5s < t <6s	Straight road	30 km/h
06	6s < t <8s	Climbing slope 10%	50 km/h
07	8s < t <10s	Straight road	5 km/h

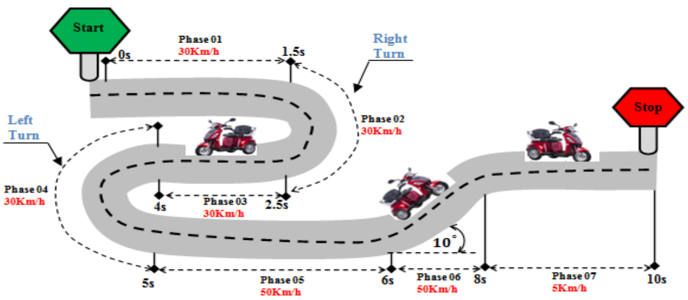


Figure 5. Specify driving road topology

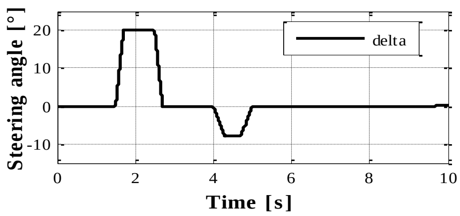


Figure 6. Steering angle variation

6. SIMULATION RESULTS

The simulations result of an electric scooter's traction system, which is powered by two 1.5 kW induction motors built into the wheels. Aims of the simulation were to compare and contrast the efficiency of two distinct control strategies on the electric scooter dynamic. The reference wheel speed shown in the topology of Figure 5 was used to simulate this system; The Aerodynamic torque is decreased when ANN-DTC control is used instead of CDTC control. 4.15 NM when using ANN-DTC and 5.82 NM when using CDTC (phase 6, see Figure 7). This number can be explained by the fact that CDTC copied using ANN-DTC has a huge frontal area. As can be observed, ANN-DTC produces a greater total resistive torque than CDTC (see Figure 8).

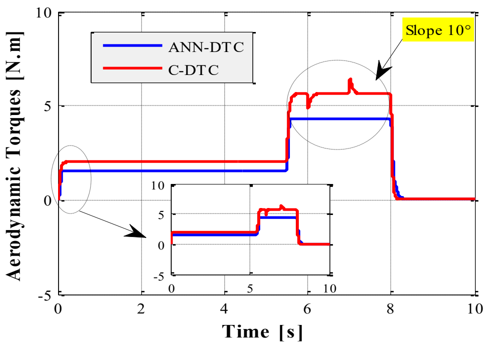


Figure 7. Scooter aerodynamics torque variation with CDTC and DTFC

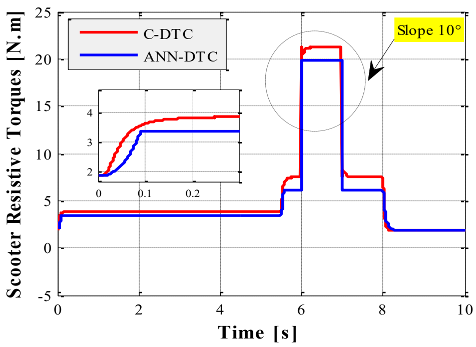
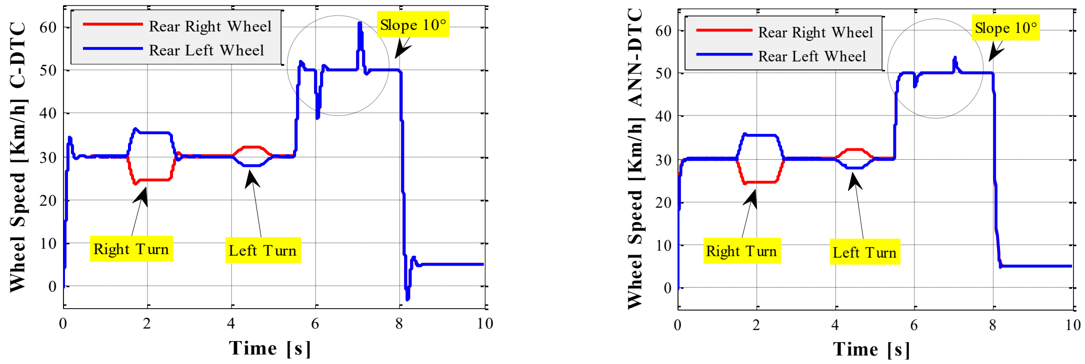


Figure 8. Globally scooter resistive torque variation with CDTC and DTFC

The driver has control over the steering angle of the front wheel, while the electronic differential has control over the speeds of the wheels that are really driving the car. Turn phase 2 involves the right driving wheel rotating faster than turn phase 1. The Figure 9 present the variation in wheel speed throughout various phases Figure 9(a) with CDTC, and Figure 9(b) with ANN-DTC, you can see how these patterns play out. A

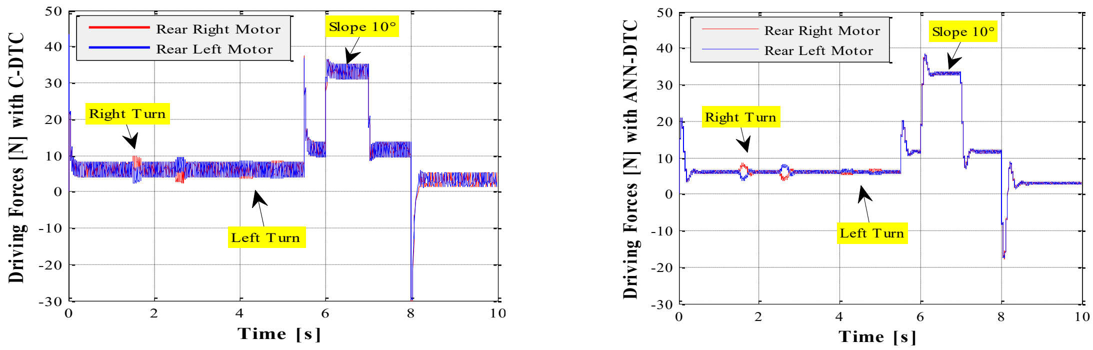
second left turn (phase 4) is taking place on the scooter, and the electronic differential is doing its thing to help it stay stable as it makes this turn.

The evolution of the electromagnetic torque generated by the three-wheeled electric scooter two propulsion motor (IM) is depicted in Figure 10(a) using the conventional DTC and Figure 10(b) using ANN-DTC control methods. The obtained findings demonstrate the proposed ANN-DTC control excellent dynamic performance in terms of torque response. Additionally, torque ripples are significantly reduced as compared to conventional direct torque control (C-DTC). This improvement is summarized in Table 3.



(a) (b)

Figure 9. Variation in wheel speed throughout various phases (a) with CDTC (b) with ANN-DTC



(a) (b)

Figure 10. Torque response developed by the two motors using (a) conventional DTC (b) ANN-DTC

Table 3. Electromagnetic torque value of each motor during the whole driving cycle

Electromagnetic Torque		Phase 01	Phase 02	Phase 03	Phase 04	Phase 05	Phase 06	Phase 07
Left Rear IM	C-DTC	2.62	0.74	2.61	2.72	4.43	11.42	1.72
	ANN-DTC	2.06	1.18	2.04	1.67	3.94	10.72	1.74
Right Rear IM	C-DTC	2.62	3.24	2.61	1.14	4.43	11.42	1.72
	ANN-DTC	2.06	2.63	2.04	2.17	3.94	10.72	1.74

7. CONCLUSION

In this work, a comparative study of two control strategies which are made to improve the dynamics of a three-wheeled electric vehicle 3WES: namely by the classic direct torque control C-DTC and DTC based on the artificial neuron network ANN-DTC, where the switch table and hysteresis regulators have been removed and replaced by artificial neuron network type regulators. Analysis of simulation results show a significant reduction in torque ripple and stator flux, low stator current distortion, thus the dynamic performance of 3WES has been improved. This improvement is clearly visible in the resistive torque responses, aerodynamic torque, distance traveled and SOC of 3WES compared to the conventional C-DTC control method.

REFERENCES

[1] A. Arif, A. Betka, and A. Guettaf, “Improvement the DTC System for Electric Vehicles Induction Motors,” *Serbian Journal of Electrical Engineering*, vol. 7, no. 2, November 2010, 149-165, doi: 10.2298/SJEE1002149A.

[2] M. R. M. Hassan, M. A. Mossa, and G. M. Dousoky, “Evaluation of Electric Dynamic Performance of an Electric Vehicle System Using Different Control Techniques,” *Electronics*, vol. 10, no. 21, p. 2586, 2021, doi: 10.3390/electronics10212586.

[3] M. Depenbrock, “Direct self-control (DSC) of inverter-fed induction machine,” in *IEEE Transactions on Power Electronics*, vol. 3, no. 4, pp. 420-429, Oct. 1988, doi: 10.1109/63.17963.

[4] I. Takahashi and Y. Ohmori, “High-performance direct torque control of an induction motor,” *IEEE Transactions on Industry Applications*, vol. 25, no. 2, pp. 257-264, March-April 1989, doi: 10.1109/28.25540.

[5] I. Takahashi and T. Noguchi, “A New Quick-Response and High-Efficiency Control Strategy of an Induction Motor,” *IEEE Transactions on Industry Applications*, vol. IA-22, no. 5, pp. 820-827, Sept. 1986, doi: 10.1109/TIA.1986.4504799.

[6] D. Casadei, G. Serra, and K. Tani, “Implementation of a direct control algorithm for induction motors based on discrete space vector modulation,” *IEEE Transactions on Power Electronics*, vol. 15, no. 4, pp. 769-777, July 2000, doi: 10.1109/63.849048.

[7] I. Boldea, L. N. Tutelea, L. Parsa, and D. Dorrell, “Automotive Electric Propulsion Systems with Reduced or No Permanent Magnets: An Overview,” *IEEE Transactions on Industrial Electronics*, vol. 61, no. 10, pp. 5696-5711, Oct. 2014, doi: 10.1109/TIE.2014.2301754.

[8] G. Cirrincione, M. Cirrincione, Chuan Lu and M. Pucci, “Direct torque control of induction motors by use of the GMR neural network,” *Proceedings of the International Joint Conference on Neural Networks*, 2003., 2003, pp. 2106-2111 vol. 3, doi: 10.1109/IJCNN.2003.1223733.

[9] O. Ellabban and H. Abu-Rub, “Torque control strategies for a high-performance switched reluctance motor drive system,” *2013 7th IEEE GCC Conference and Exhibition (GCC)*, 2013, pp. 257-262, doi: 10.1109/IEEEGCC.2013.6705786.

[10] B. Kosko, “Neural networks and fuzzy systems: A dynamical systems approach to machine intelligence,” *The Knowledge Engineering Review*, vol. 10, no. 2, pp. 219-220, 1995, doi: 10.1017/S0269888900008225.

[11] R. Abdel-Fadil and L. Számel, “Predictive Direct Torque Control of Switched Reluctance Motor for Electric Vehicles Drives,” *Period. Polytech. Elec. Eng. Comp. Sci.*, vol. 64, no. 3, pp. 264–273, 2020, doi: 10.3311/PPee.15496.

[12] Q. Liu and K. Hameyer, “Torque Ripple Minimization for Direct Torque Control of PMSM With Modified FCSMPC,” *IEEE Transactions on Industry Applications*, vol. 52, no. 6, pp. 4855-4864, Nov.-Dec. 2016, doi: 10.1109/TIA.2016.2599902.

[13] Z. Chen, W. Tu, L. Yan and G. Luo, “Dynamic Cost Function Design of Finite-Control-Set Model Predictive Current Control for PMSM Drives,” *2019 IEEE International Symposium on Predictive Control of Electrical Drives and Power Electronics (PRECEDE)*, 2019, pp. 1-6, doi: 10.1109/PRECEDE.2019.8753287.

[14] V. P. Vujičić, “Minimization of Torque Ripple and Copper Losses in Switched Reluctance Drive,” *IEEE Transactions on Power Electronics*, vol. 27, no. 1, pp. 388-399, Jan. 2012, doi: 10.1109/TPEL.2011.2158447.

[15] S. Jebarani Evangeline and S. Suresh Kumar, “Torque Ripple Minimization of switched reluctance drives - A survey,” *5th IET International Conference on Power Electronics, Machines and Drives (PEMD 2010)*, 2010, pp. 1-6, doi: 10.1049/cp.2010.0177.

[16] S. Kaboli, M. R. Zolghadri and A. Emadi, “Hysteresis band determination of direct torque-controlled induction motor drives with torque ripple and motor-inverter loss considerations,” *IEEE 34th Annual Conference on Power Electronics Specialist, 2003. PESC '03.*, 2003, pp. 1107-1111 vol. 3, doi: 10.1109/PESC.2003.1216604.

[17] T. Vajsz, L. SzÃ¡mel, and G. RÃ¡cz, â€œA Novel Modified DTC-SVM Method with Better Overload-capability for Permanent Magnet Synchronous Motor Servo Drives,” *Periodica Polytechnica Electrical Engineering and Computer Science*, vol. 61, no. 3, p. 253, Jun. 2017, doi: 10.3311/PPee.10428.

[18] N. Nouria, G. Brahim, G. Abdelkader, and B. Cherif, “Improved DTC strategy of an electric vehicle with four in-wheels induction motor drive 4WDEV using fuzzy logic control,” *International Journal of Power Electronics and Drive System (IJPEDS)*, vol. 12, no. 2, pp. 650-661, Jun 2021, doi: 10.11591/ijpeds.v12.i2.pp650-661.

[19] A. Ghezouani, B. Gasbaoui, N. Nair, O. Abdelkhalek, and J. Ghouili, “Comparative study of PI and fuzzy logic based speed controllers of an EV with four in-wheel induction motors drive,” *Journal of Automation, Mobile Robotics and Intelligent Systems*, vol. 13, no. 2, pp. 43-54, Nov 2018, doi: 10.14313/JAMRIS_3-2018/17.

[20] R. Abdel-Fadil and László Számel, “Predictive Direct Torque Control of Switched Reluctance Motor for Electric Vehicles Drives,” *Periodica Polytechnica Electrical Engineering and Computer Science*, vol. 64, no. 3, pp. 264–273, 2020, doi: 10.3311/PPee.15496.

[21] R. Morales-Caporal, M. E. Leal-López, J. de Jesús Rangel-Magdaleno, O. Sandre-Hernández and I. Cruz-Vega, “Direct torque control of a PMSM-drive for electric vehicle applications,” *2018 International Conference on Electronics, Communications and Computers (CONIELECOMP)*, 2018, pp. 232-237, doi: 10.1109/CONIELECOMP.2018.8327204.

[22] L. Fu, *Neural Networks in Computer Intelligence*, New York, US: McGraw-Hill Inc., pp. 153-264, 1994.

[23] M. T. Hagan and M. B. Menhaj, “Training feedforward networks with the Marquardt algorithm,” *IEEE Transactions on Neural Networks*, vol. 5, no. 6, pp. 989-993, Nov. 1994, doi: 10.1109/72.329697.

[24] C. Gan, J. Wu, Q. Sun, S. Yang, Y. Hu, and L. Jin, “Low-cost direct instantaneous torque control for switched reluctance motors with bus current detection under soft-chopping mode,” *IET Power Electronics*, vol. 9, no. 3, pp. 482–490, 2016, doi: 10.1049/iet-pel.2015.0370.

[25] J. Ye, B. Bilgin, and A. Emadi, “An Offline Torque Sharing Function for Torque Ripple Reduction in Switched Reluctance Motor Drives,” *IEEE Transactions on Energy Conversion*, vol. 30, no. 2, pp. 726-735, June 2015, doi: 10.1109/TEC.2014.2383991.

[26] Chunhua Zang, “Vector controlled PMSM drive based on fuzzy speed controller,” *2010 The 2nd International Conference on Industrial Mechatronics and Automation*, 2010, pp. 199-202, doi: 10.1109/ICINDMA.2010.5538336.

[27] J. A. Makwana, P. Agarwal and S. P. Srivastava, “Novel simulation approach to analyses the performance of in-wheel SRM for an Electrical Vehicle,” *2011 International Conference on Energy, Automation and Signal*, 2011, pp. 1-5, doi: 10.1109/ICEAS.2011.6147103.

[28] A. Laguidi, A. Hazzab, O. Boughazi, and M. Habbab, “Adaptative self-tuning Fuzzy backstepping controller for the control of electrc vehicule with two-motor-wheel drive,” *Acta Electrotechnica et Informatica*, vol. 19, no. 2, 2019, 38–44, doi: 10.15546/aeei-2019-0013

[29] J. O. Estima and A. J. Marques Cardoso, “Efficiency Analysis of Drive Train Topologies Applied to Electric/Hybrid Vehicles," *IEEE Transactions on Vehicular Technology*, vol. 61, no. 3, pp. 1021-1031, March 2012, doi: 10.1109/TVT.2012.2186993.

BIOGRAPHIES OF AUTHORS

Bachiri Hassane He is an Assistant lecturer in Electrical engineering Department of Tahri Mohammed Bechar university, (Algeria). He received B.Eng. and M. Eng degree in Electrical Engineering from Tahri Mohammed Bechar university, (Algeria) in 2010, and 2016, respectively, He contributed to the manufacture of an electric motor with DTC method and the research process in the electric car industry and wireless communications. His research interests include the field of digital design, industrial applications, industrial electronics, power electronics, motor drives, renewable energy, artificial intelligence, intelligent control and digital library. e-mail address: bachirihassane@yahoo.com.

Brahim Gasbaoui He received B.Eng. in electrical engineering from the University Ibn-Khaldoun, Tiaret in 1993, and an MSc degree from Tahri Mohammed Bechar university, (Algeria).in 2008, He received Ph.D. degree from same University where he is Currently a professor in electrical engineering. His research interests include power electronics robust control for electric vehicle and propulsion system, power electronics, antilock brake systems, anti-skid control for electric vehicles drive e-mail address: gasbaoui_2009@yahoo.fr.

Abdelkader Ghezouani He graduated from the University of Telemen, having received L.Sc. and M.Sc. degrees in Electrical Engineering in 2009 and 2011 respectively. Since 2015, he has been a Ph.D. Candidate in the Department of Electrical Engineering at the University of Becher, Algeria. His research interests include sliding mode control, Non-Linear Control, especially the control of electrical machines with applications to Electrical Vehicle Drive. e-mail address: gheabd@ymail.com.

Nair Nouria She received MSc degree in in electrical engineering, in 2001 from Tahri Mohammed Bechar university, (Algeria), She received M. Eng degree in electrical engineering in 2012 from same university, she is preparing Ph.D. degree in the Control of an urban electric vehicle with four driving wheels, using Artificial intelligence as fuzzy logic in its control. She is currently a Research member in the Smart Grid and Renewable energy Laboratory since 2016, Her main Research activity is focused on vehicle electric. Correspondence address: Institute of Science &Technology, University of Becher, BP 417 Route de Kenadsa, 08000 Becher, Algeria; e-mail: nairnouria.2017@gmail.com.